

Sensorless Passivity Based Control of a DC Motor

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Abstract -- In last couple of decades, the control of motors has increased drastically. With this increase, current control techniques are developed. In sensor-less passivity control of a DC Motor the term passivity means the property of stability in an input and output. To maintain the stability at the input side the solar pv panel is connected with MPPT which extract maximum and stable voltage. For output we simultaneously regulate, both, the output voltage of the SEPIC-converter to a value larger than the solar panel output voltage, and the speed of motor, in any of the turning senses, so that it tracks a pre-specified constant reference. For a sensor less current control of a PMDC motor, its small-signal model that contains a number of parasitic parameters the observed current may diverge due to the parasitic resistors and the forward conduction voltage of the diode. Moreover, the divergence of the observed current will cause steady state errors in the output voltage a self-correction differential current observer (SDCO) is proposed to eliminate this steady-state error and gain high transient response speed. By carrying out a series of MATLAB simulation verifications, further investigation proves that the proposed algorithm has good robustness.

Keywords: Sensor less, SEPIC converter, Differential current observer, Self-correction , PMDC motor, PCC, MPPT.

I.INTRODUCTION

In recent years, digital control for a permanent magnet dc motor has become one of the research hot topics. Compared with the voltage control mode, the current control mode has higher response speed and larger loop gain bandwidth. However, in current control mode, when the pulse width modulation (PWM) duty ratio is higher than 50%, a slope compensation circuit becomes necessary to maintain system stability. Due to its high robustness and high response speed, predictive current control (PCC) has been brought into sepic converter current control loop design and has been widely investigated. The current sensors have different advantages and drawbacks, and thus could meet different requirements. However, existing techniques might not suit applications which require isolation with minimal price, power loss and size. Therefore, a current observer (CO) turns out to be a suitable substitute for conventional current sensors in digitally controlled converters. The cost, size and power consumption can be reduced since it does not need any auxiliary hardware, even though the accuracy might be affected by the voltage ripple or the mismatches between the observer and the converter. In PCC mode, the inductor current of the next switching cycle should be predicted, and the duty ratio for the next switching cycle can be calculated according to the reference current and predicted current.

In this application, the power converters transfer the Solar panel power to the load represented by a DC motor. As an advanced current control strategy, the predictive current control (PCC) has the characteristics of high robustness and high response speed. It can be combined with the current observer to realize sensor less PCC (SPCC). Both the PCC and current observer technologies have been widely investigated. For the PCC, an algorithm was investigated to eliminate the inductor current disturbance in one switching cycle in peak, average, and valley current control modes. However, in order to maintain the current control loop stability, the specific combination of current control mode with pulse width modulation (PWM) modulation scheme should be obeyed, and it restrains the flexibility of system design.

II PROPOSED SYSTEM FOR PASSIVITY CONTROL OF PMDC MOTOR

A. Basic Current Observer

The construction of SEPIC DC-DC converter with the CO based PCC controller, is shown in Figure 1. The controller is a dual-loop system. The voltage loop is a PI compensator, which outputs the reference current I_{REF} . The current loop is the PCC controller, which calculates the duty ratio for the next switching cycle. In every switching cycle, the voltage sampling, the PI regulation, the current sensing and the PCC regulation are processed in sequence. In this way, the current error could be eliminated in two switching cycles.

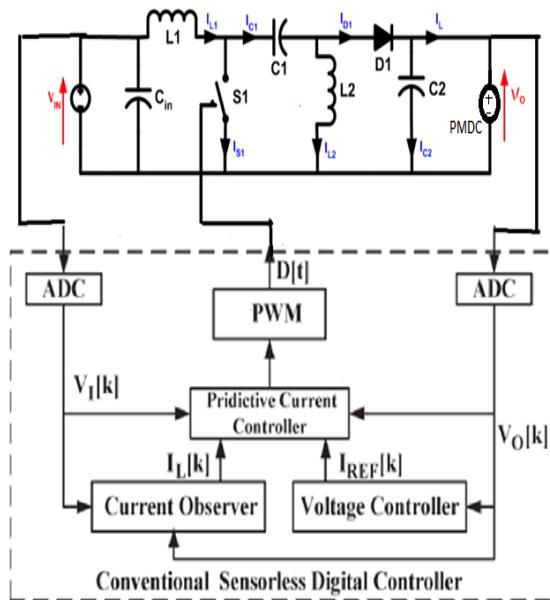


Figure 1.SEPIC converter with the CO based PCC controller

2. Differential Current Observer

After involving the self-correction module into the current observer, the output voltage steady-state error can be eliminated, and IL tends to be constant. However, the problem still exists in two respects. First, the predicted current IL is still increasing, eventually leading to the calculation result overflowing. More importantly, the influences on the parasitic parameters, e.g., device aging, will diverge I_L from the actual inductor current. As shown in Fig.4, in order to deduce $D(k + 1)$, it is only necessary to calculate ΔI rather than IL . After extracting common factor $1/sT$, ΔI becomes

$$\Delta I = I_{REF} - I_L = \frac{1}{sT} (\Delta I_{REF} - \Delta I_L) = \frac{1}{sT} \Delta I' \quad (11)$$

In (11), ΔI_{REF} and ΔI_L are the differential values of I_{REF} and I_L , respectively. When the system reaches their steady states, both of them converge to zero, and the calculation overflow can be effectively avoided.

The current observer equation in the continuous domain can be converted, i.e.,

$$I_L = \frac{1}{sT} [V_{IN} - V_O(1 - D)] \quad (12)$$

Then the differential current observer is

$$\Delta I_L = \frac{T}{L} [V_{IN} - V_O(1 - D)] \quad (13)$$

Whereas ΔI_{REF} can be calculated by

$$\Delta I_{REF} = K_P (1 + 1/sT) sT \quad (14)$$

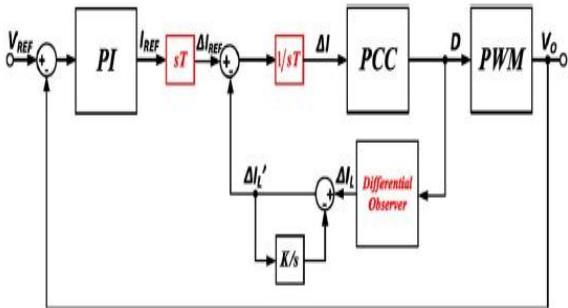


Figure 4 Block diagram of the current controller with differential observer

The block diagram of the current controller with differential observer is shown in Fig. 3. Compared with Fig. 4, additional modules are added, as marked in red.

III. EXPERIMENTAL RESULTS

To verify the proposed algorithm, experiments are carried out with a DC motor with sepic converter interface. SIMULINK model is created PMDC motor/SEPIC converter combination powered via a solar panel. This model contains renewable solar energy source, permanent magnet DC motor, and predictive current controller, control circuit which has PI controller, PWM and sepic converter interface. The waveforms based on these calculations are shown as follows

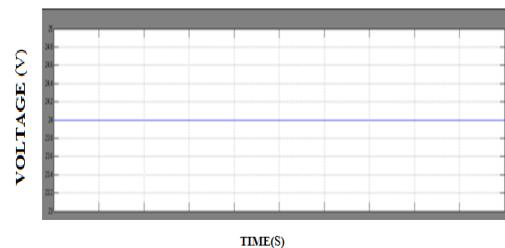


Figure 5 Input voltage

Fig 5 shows the input voltage of 24V, which is obtained from solar mppt. The MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

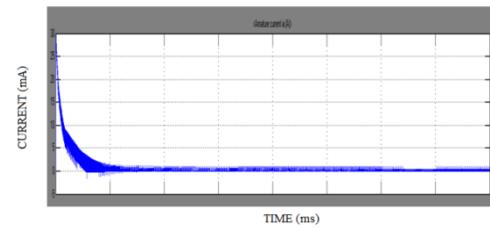


Figure 6 Armature current of the PMDC motor

Fig. 6 shows the output current obtained from simulation. On this basis, the system small-signal model, including the parasitic parameters, is constructed and analyzed. Then an SCDO is proposed. PMDC motor has high starting current and its getting reduced after the motor start to run at its desired speed.

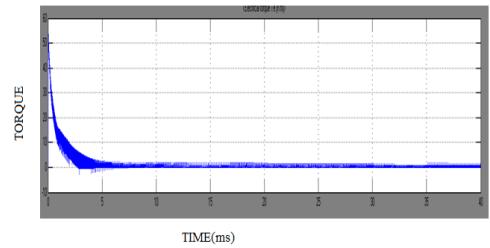


Figure 7 Torque of the PMDC motor

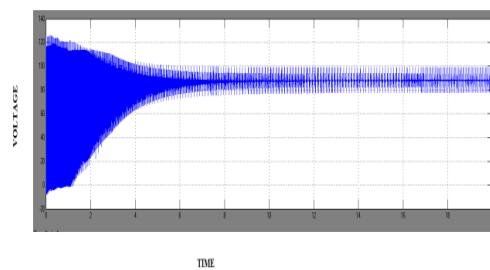


Figure 8 output voltage of the PMDC motor

The basic cause of the output voltage steady-state error in a sensor less current-controlled sepic converter has been eliminated in fig 8 and it is proved through theoretical derivations.

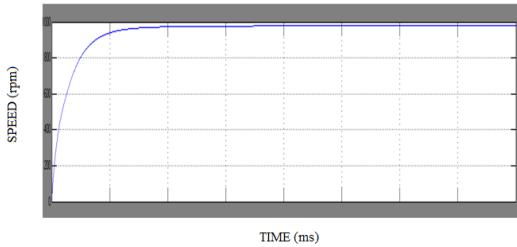


Figure 9 Speed of the PMDC motor

Fig 9 shows the speed of the motor and Fig 7 shows the torque of the motor. The above figures are matched with the practical performance of the PMDC motor. When the speed increases the torque and the armature current decreases. Speed is inversely proportional to the torque.

On this basis, the compensation strategy for output voltage sampling in both current loop and voltage loop has been proposed. In addition, the system modeling error caused by the parasitic parameters and nonlinear factors has been also compensated. The system ultimately achieves high-precision sensor less predictive peak current control without the voltage steady-state error with the comprehensive compensation strategy.

III CONCLUSION

The basic cause of output voltage steady-state error in a sensor less current controlled PMDC motor has been established in theory. On this basis, the system small-signal model, including the parasitic parameters, is constructed and analyzed. Then an SCDO is proposed. Simulation shows that the proposed algorithm is very robust. In addition, its computational complexity is low and easy to implement. With the proposed algorithm, the system ultimately achieves no voltage steady-state error with good transient performance despite parasitic parameters variation. Experimental results show that the control of permanent magnet DC motor is proposed in this paper is accurate and effective and has a good theoretical and practical application potential. The result of this property would be the increase of speed and efficiency.

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DC motor is proposed in this paper is accurate and effective and has a good theoretical and practical application potential. The result of this property would be the increase of speed and efficiency. This system is suitable for industrial applications.

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